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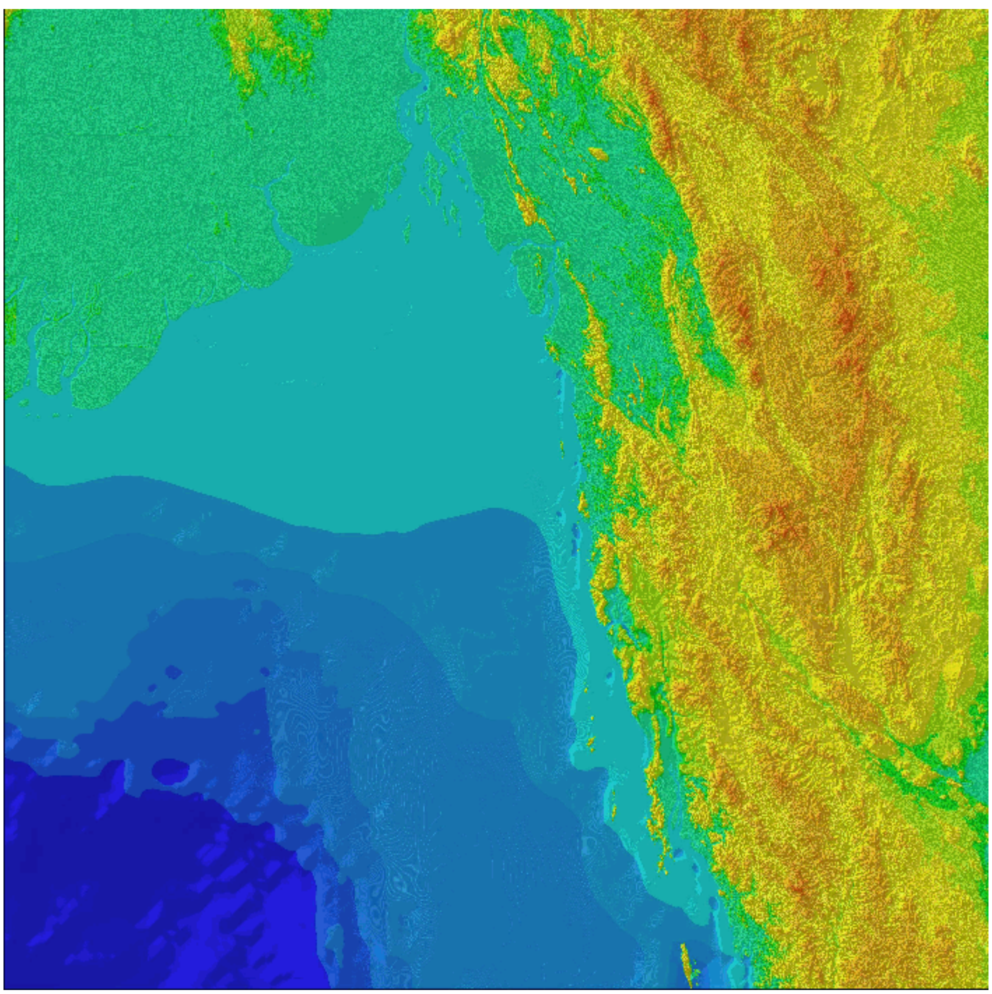
Generating a Coastal Boundary and Merging Bathymetry with DTED® Level 1 Using ArcInfo: A Modeling and Simulation Application

June 2000

James J. Damron



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Abstract
The Environmental Systems Research Institutes (ESRI) Digital Chart of the World (DCW) are vector data created from the National Imagery and Mapping Agencys (NIMA) (formerly the Defense Mapping Agencys (DMA)) Operational Navigation Chart (ONC) at 1:1,000,000 scale. Use of DCW poses a potential problem when working with other digital data at higher resolutions. The PONET and POLINE vector layers in the DCW, which identify a coastal boundary, are not sufficient for modeling and simulation. The DCW coastal layers do not register accurately with Digital Terrain Elevation Data (DTED®) Level 1. DTED Level 1 has an accuracy equivalent to a 1:250,000-scale map product. DTED Level 1 is the main elevation source used for modeling and simulation to create a terrain surface in a virtual world. The coastal layers in DCW are quite effective for most Geographic Information System (GIS) pplications but, for modeling and simulation purposes, the vector layers for a coastal boundary do not correlate with DTED Level 1 (Figure 1).

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13. ABSTRACT *(Maximum 200 words)*

Environmental Systems Research Institute's (ESRI) Digital Chart of the World (DCW) are vector data created from the National Imagery and Mapping Agency's (NIMA) Operational Navigation Chart (ONC) at 1:1,000,000 scale. Digital Terrain Elevation Data (DTED) Level 1 has an accuracy equivalent to a 1:250,000-scale map product. When DTED Level 1 and DCW coastline vectors do not correlate, a way is needed to generate coastline vectors form DTED Level 1. Generating a coastline from DTEC Level 1 allows for a correlated ocean-land interface not before possible over large areas in the modeling and simulation community. Using the newly generated coastline from DTED Level 1, bathymetric can be merged with DTED Level 1 for constructing a joint land, sea, and air modeling and simulation virtual database. This report addresses problems the modeling and simulation community has been burdened with for many years. The first method will provide steps needed to generate a coastal boundary vector from DTED Level 1 when other vector products are available and do not correlate to DTED Level 1. The second method will use the new coastline as a common boundary to merge bathymetry with DTED Level 1. Using ArcInfo version 8.0.1 with the GRID extension, it was possible to generate a coastline from DTEC Level 1 and use the common boundary to merge bathymetry and DTED Level 1 elevation data into a bathymetry/terrrain data set for modeling and simulation database construction.

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PREFACE

This project was completed during the period February to April 2000. Mr. Thomas E. Jorgensen was Chief, Terrain Data Representation Branch, and Mr. William Z. Clark was Acting Director, Topographic Research Division during this period.

Colonel James A. Walter was the Director of the U.S. Army Engineer Research and Development Center's (ERDC) Topographic Engineering Center (TEC) at the time of publication of this report.

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GENERATING A COASTAL BOUNDARY AND MERGING BATHYMETRY WITH DTED® LEVEL 1 USING ARCINFO: A MODELING AND SIMULATION APPLICATION

INTRODUCTION

The Environmental Systems Research Institute's (ESRI) Digital Chart of the World (DCW) are vector data created from the National Imagery and Mapping Agency's (NIMA) (formerly the Defense Mapping Agency's (DMA)) Operational Navigation Chart (ONC) at 1:1,000,000 scale. Use of DCW poses a potential problem when working with other digital data at higher resolutions. The PONET and POLINE vector layers in the DCW, which identify a coastal boundary, are not sufficient for modeling and simulation. The DCW coastal layers do not register accurately with Digital Terrain Elevation Data (DTED®) Level 1. DTED Level 1 has an accuracy equivalent to a 1:250,000-scale map product. DTED Level 1 is the main elevation source used for modeling and simulation to create a terrain surface in a virtual world. The coastal layers in DCW are quite effective for most Geographic Information System (GIS) applications but, for modeling and simulation purposes, the vector layers for a coastal boundary do not correlate with DTED Level 1 (Figure 1).

This report addresses two problems the modeling and simulation community has endured when creating virtual databases. The first procedure will detail how to generate a coastal boundary vector from DTED Level 1 when other vector products are not adequate. In the second procedure, the new coastline will be used as a common boundary to merge bathymetry with DTED Level 1. ArcInfo version 8.0.1 with the GRID extension was the GIS software package used for this project.

COASTAL BOUNDARY

The coastal boundary of any area is mainly dependant on tidal variations. This may present problems when one decides to generate a coastal boundary from another source, such as DTED Level 1. The actual coastal boundary for mapping purposes is the average of the tidal variation usually called mean sea level (MSL). There are no well-defined ocean-land boundary data in DTED Level 1, but generating a coastal boundary from these data will provide better correlation between the ocean-land boundary, since the elevation data is in ellipsoid heights.

The coastal generation methodology will take several steps. This section will illustrate how to create a coastal boundary vectors that correlates with DTED Level 1. First, the *SETNULL* function was used to eliminate the land terrain from the ocean surface at the GRID prompt. The following string *oceannull = setnull(mergeall > 0, mergeall)* was used to set all data values above 0 to NODATA. The ocean surface can be replaced by NODATA values in the same *SETNULL* process, but either land or ocean are sufficient. Second, the *GRIDPOLY* command was issued to generate a vector coverage with the command line *gridpoly oceannull oceancov 1* at the Arc prompt. Third, the *GENERALIZE* command was used to eliminate the boxy appearance of the newly created *oceancov* vectors by using the string *generalize oceancov*

oceangen75 75 pointremove. In Figure 2, the vectors created in step 2 of the *GRIDPOLY* conversion are colored white and appear boxy. The effects of the *GENERALIZE* command in step 3 are apparent in Figure 2 by the elimination of the boxy appearance of the lines colored magenta.

In ArcEdit, a basic cleanup of the vectors is needed to create a usable vector coverage. Removal of dangling short lines, snapping lines together, and other procedures are needed before continuing on to the next step. In Figure 3, the ArcEdit cleanup is completed with newly generated coastlines correlating better to DTED Level 1 at this stage. A closer view in Figure 4 shows the better correlation of the generated coastlines to DTED Level 1.

Fourth, all the lines were selected using the *SELECT* command with the *all* option at the ArcEdit prompt with the string *select all*. Fifth, the *GRAIN* command is issued with a distance set at 75 m with the following string *grain 75*. Sixth and final step, the *SPLINE* command was used to provide curvature to the vector coverage and is more representative of the coastline. The effect of the *SPLINE* command is shown in Figure 5 with the new coastal lines shown in green. In Figure 6, a closer view of the same area shows the splined coastal lines correlating better with DTED Level 1. A comparison of the generalized vectors and splined vectors are shown in Figure 7. Two large lake boundaries also were generated in the coastline generation method by selecting elevations at 230 m and 134 m above sea level.

The improved correlation of the coastal boundary vectors within DTED Level 1 are apparent in several figures. The magenta-colored and green-colored lines represent the DTED Level 1-generated lines. The white-colored lines represent the DCW coastlines. The improved correlation is apparent in Figure 8 with the generated vectors lining up with DTED Level 1. The DCW coastal lines are offset by as much as 1,000 m, or more, in most cases, compared to the DTED Level 1-generated lines. Also, the DCW coastal lines are very coarse and generalized compared to the DTED Level 1-generated lines. In Figures 9, 10, and 11, the coastal and island boundaries are correlating better to DTED Level 1 data than the DCW coastal lines. It is apparent that smaller coastal island boundaries are captured and better correlated to DTED Level 1 with coastline generation methods than the DCW coastal lines shown in Figure 12. This improvement will help provide better correlation between coastal features and elevation data not before possible in modeling and simulation from other sources of data. A flow diagram in Figure 13 provides the steps involved with generating a coastal boundary from DTED Level 1.

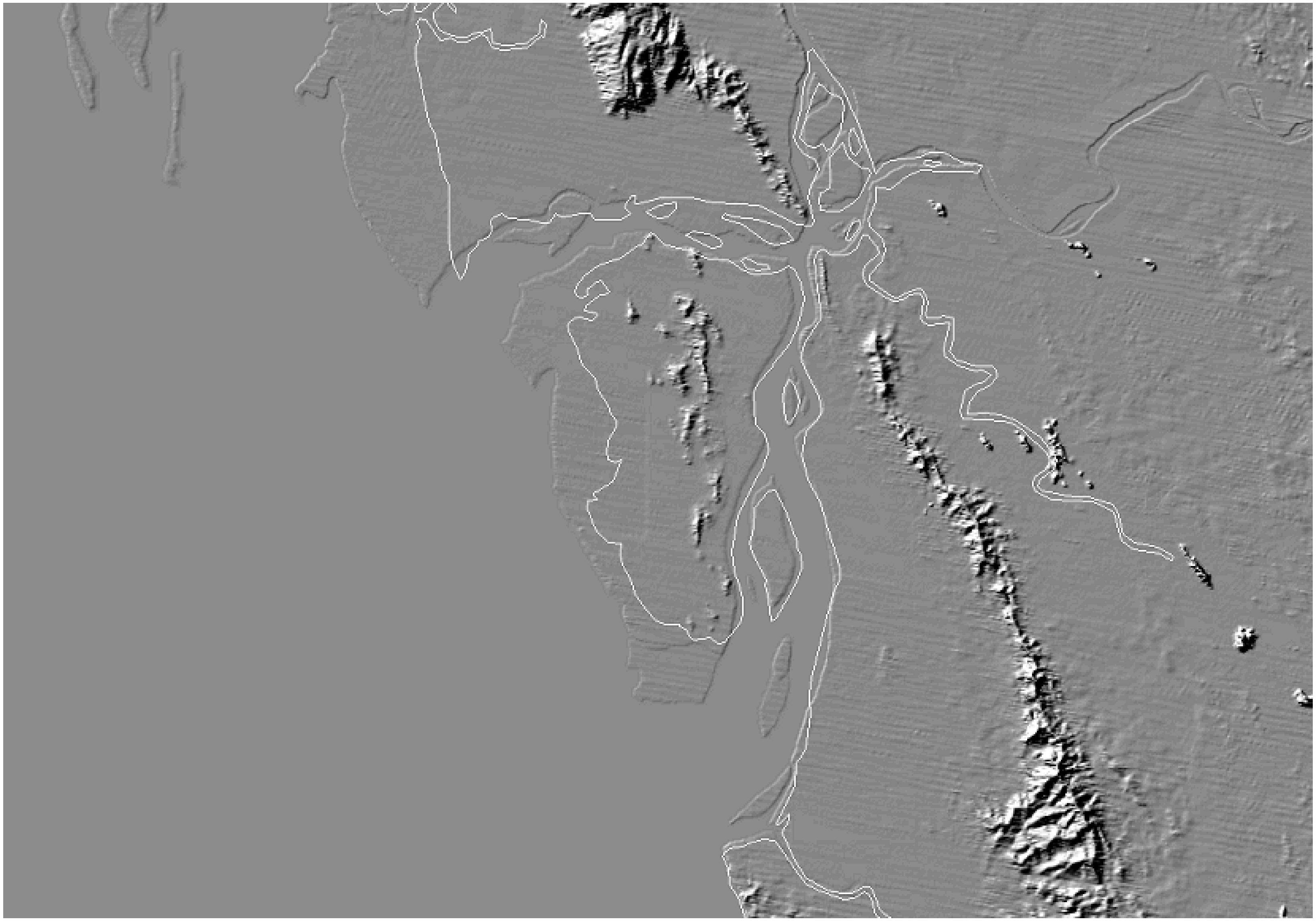

Figure 1. DTED Level 1 with DCW Coastal Lines

Figure 2. Gridded Lines and Generalized Coastal Lines

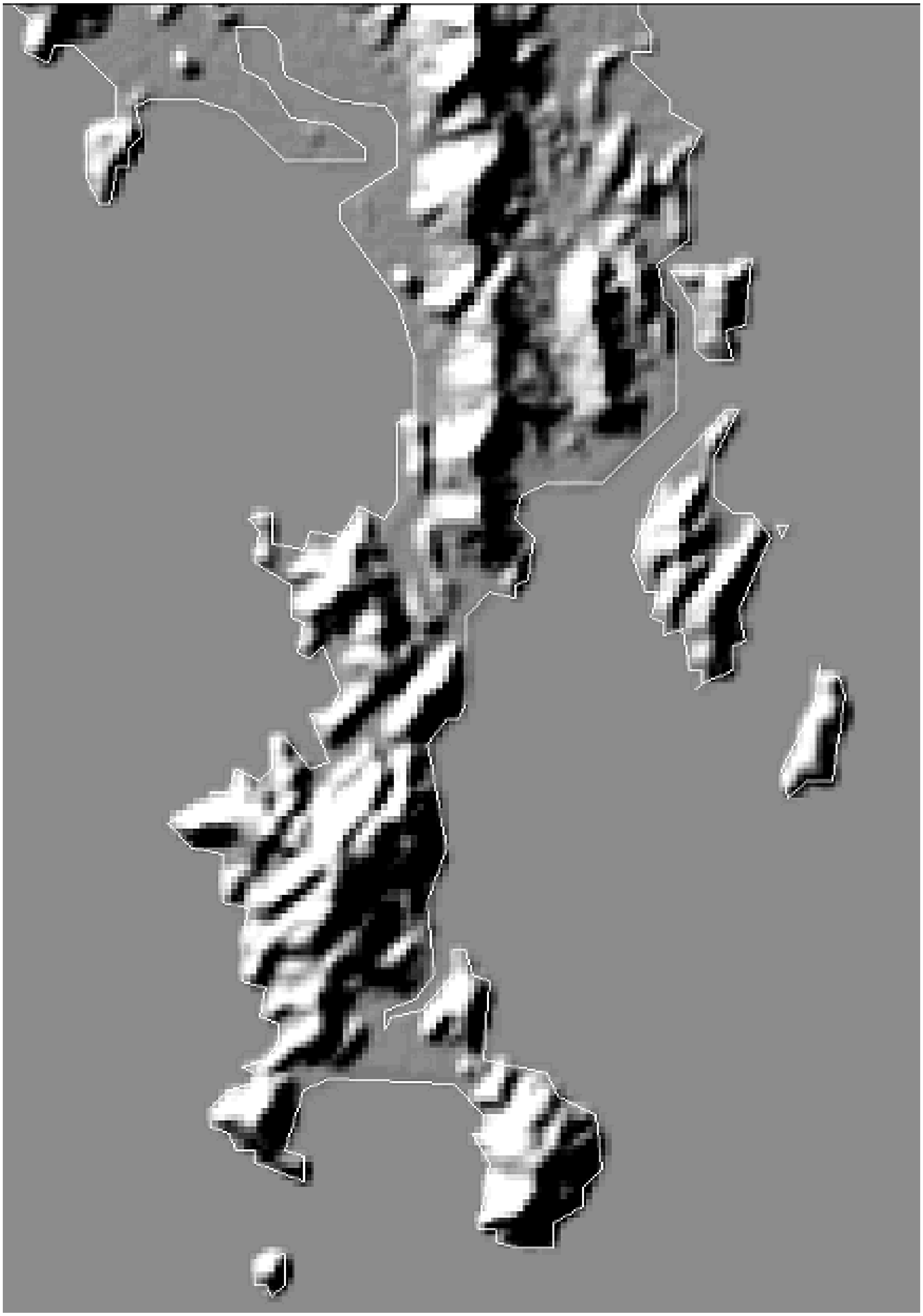

Figure 3. Generalized Coastline

Figure 4. Zoomed-in View of Figure 3

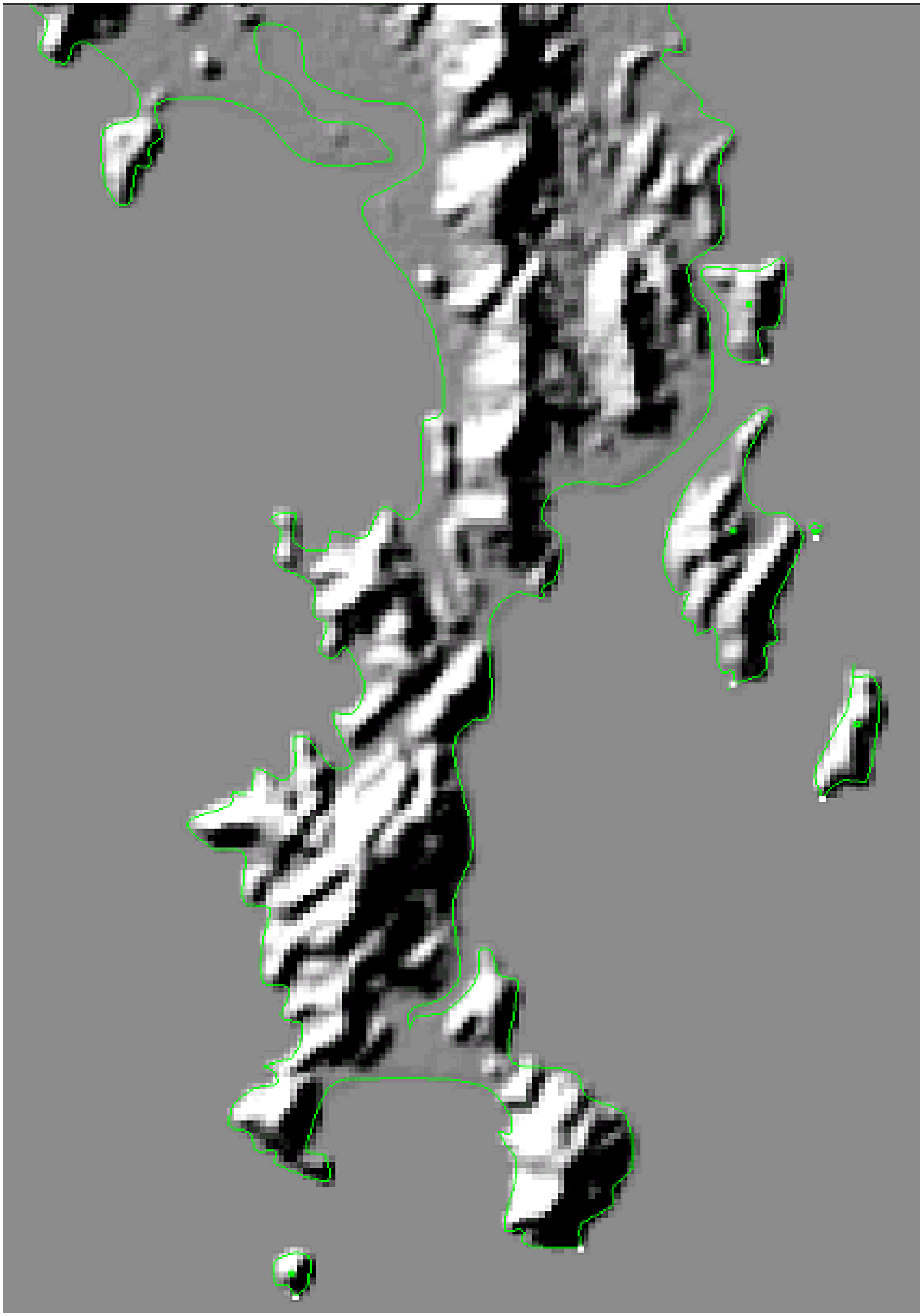

Figure 5. Splined Coastal Lines


Figure 6. Zoomed-in View of Figure 5

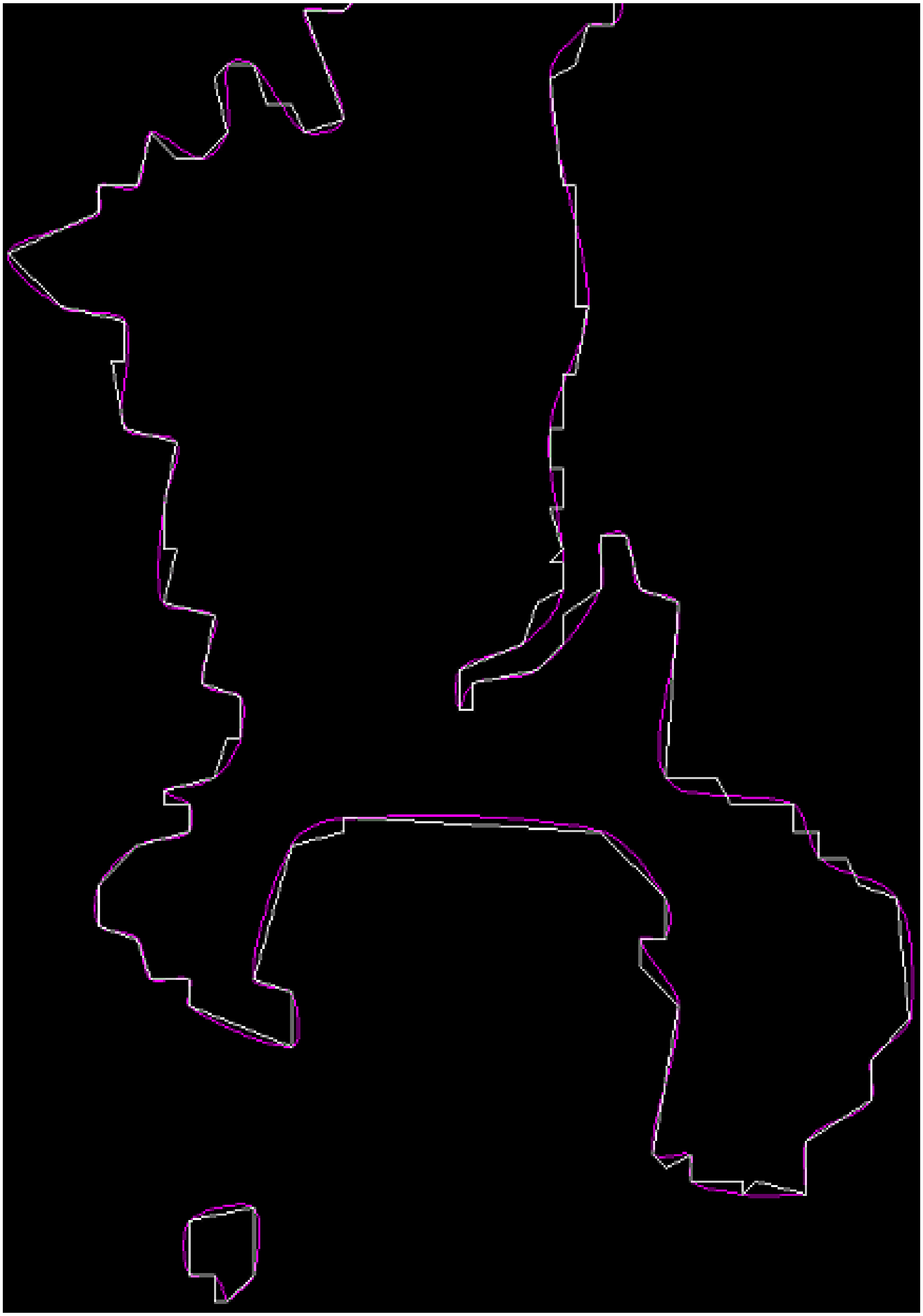

Figure 7. Generalized versus Splined Comparison

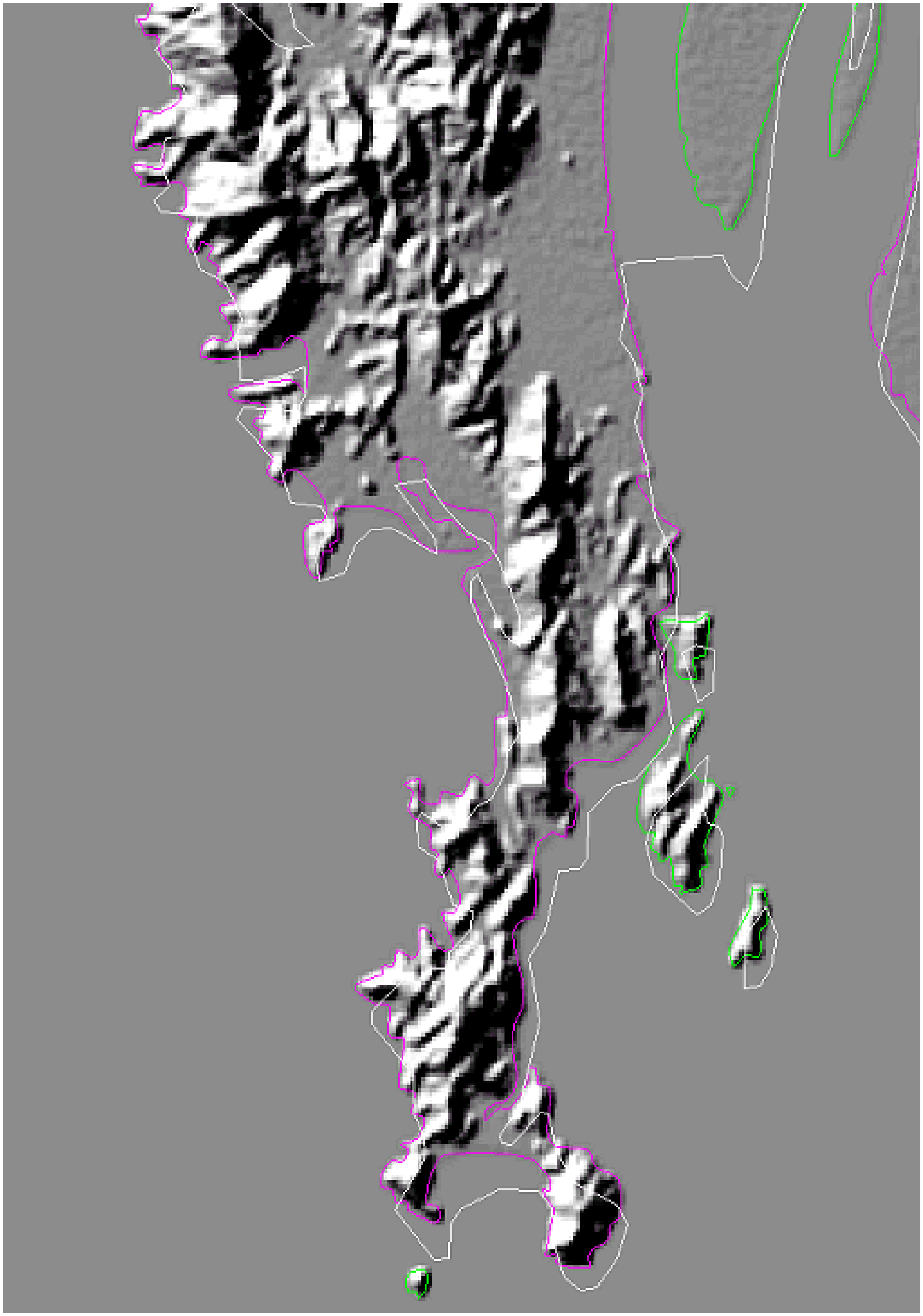

Figure 8. DCW Coastal Lines and DTED Level 1-Generated Coastal Lines

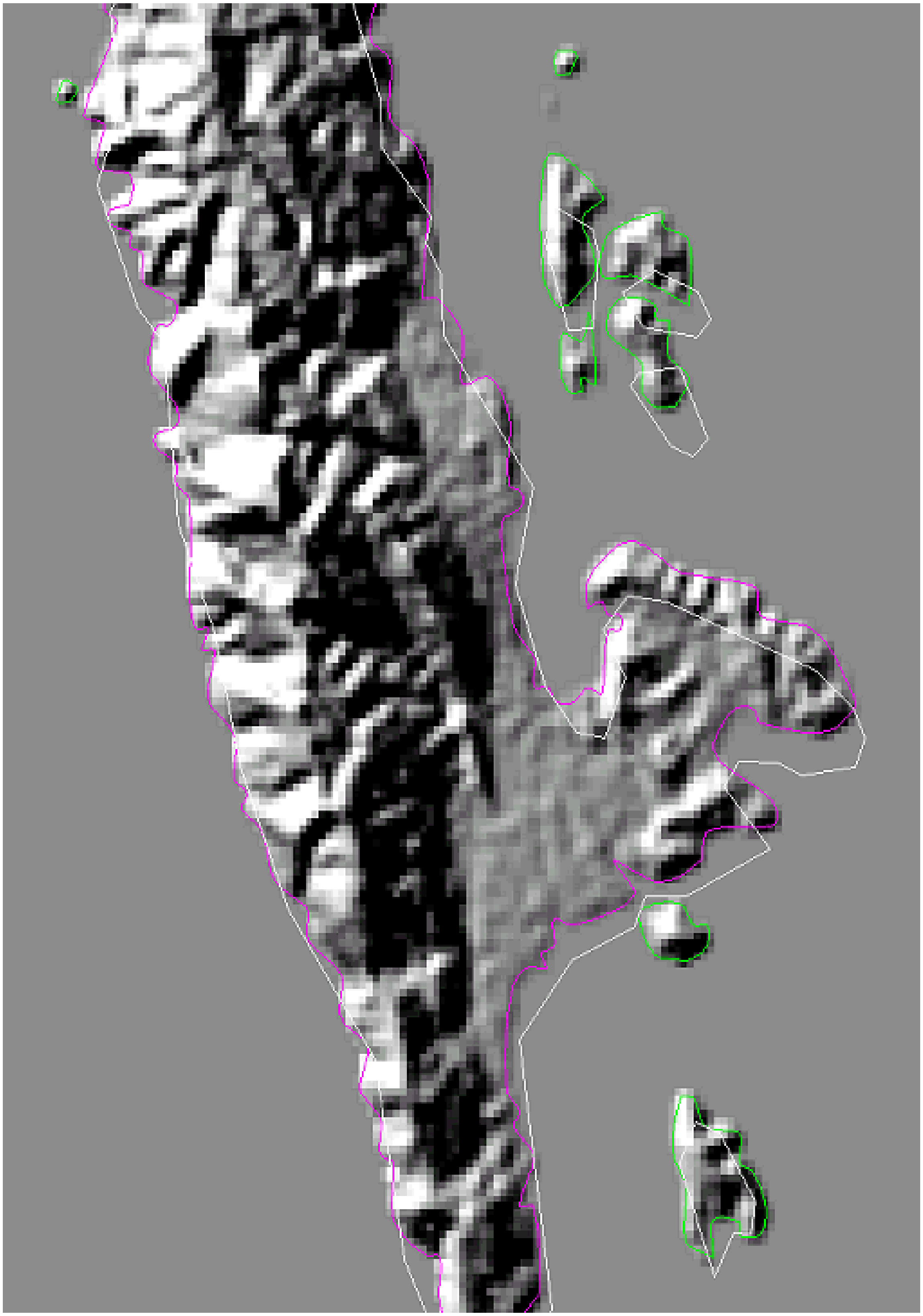

Figure 9. DCW Coastal Lines and DTED Level 1-Generated Coastal Lines

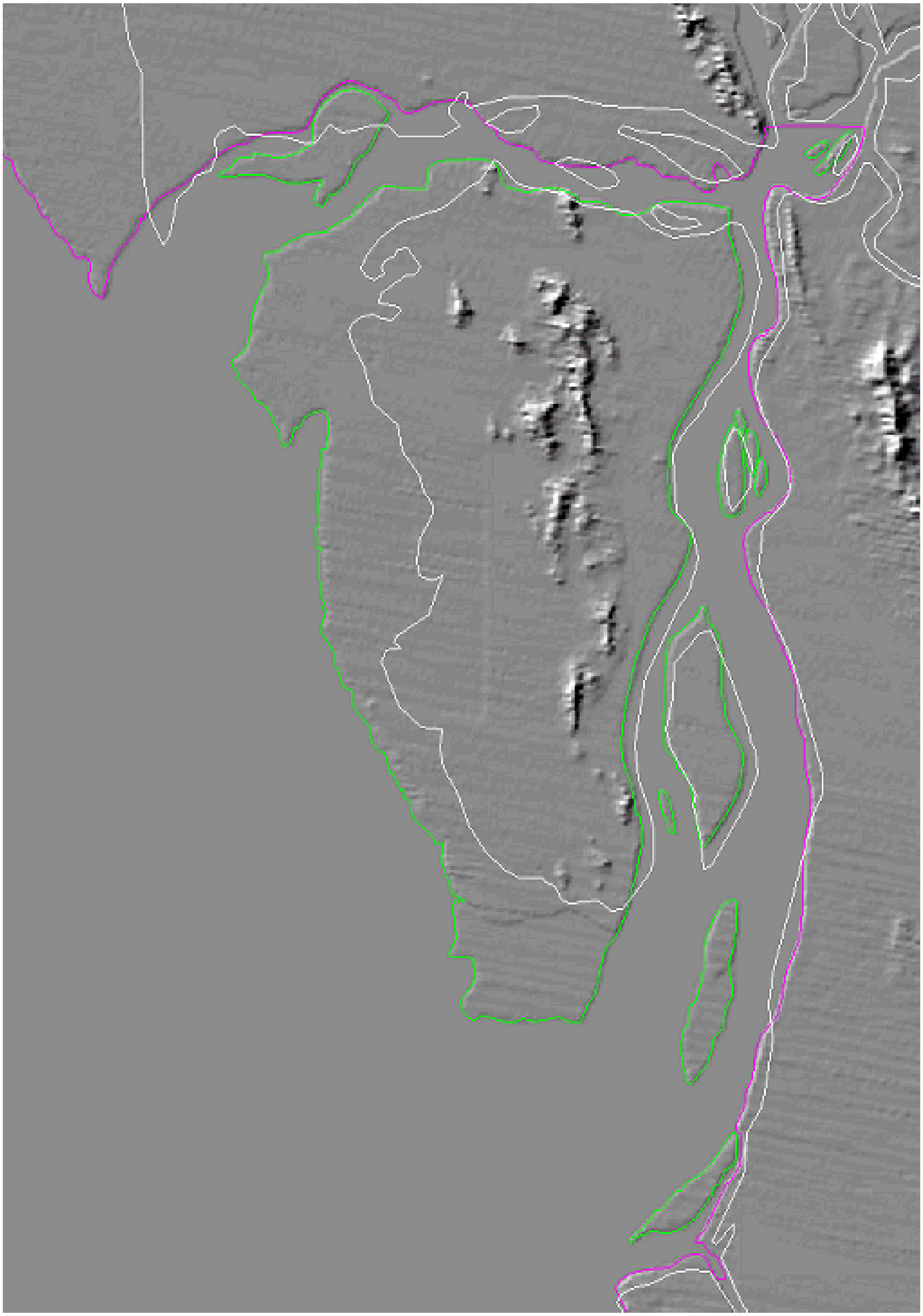

Figure 10. DCW Coastal Lines and DTED Level 1-Generated Coastal Lines

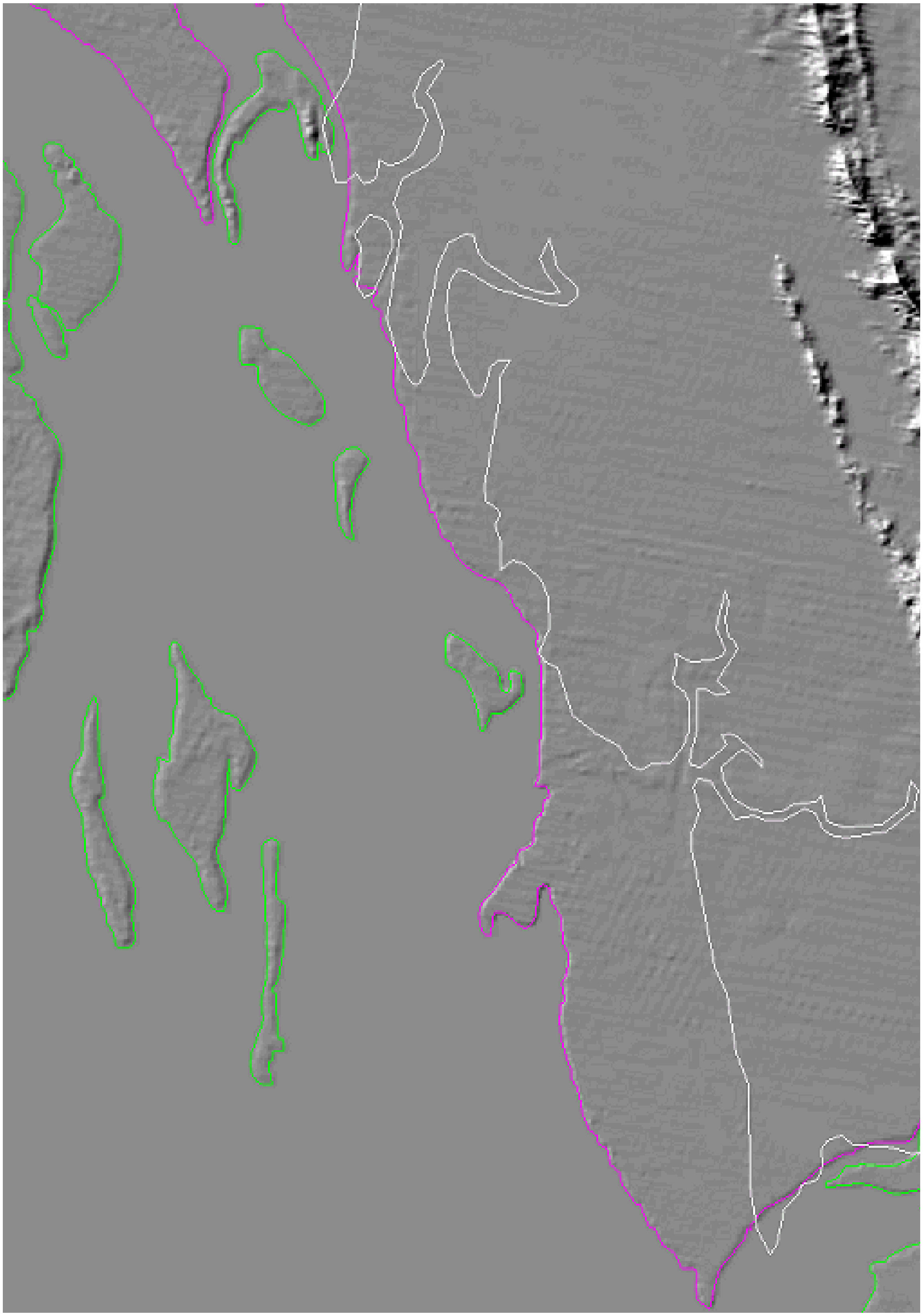

Figure 11. DCW Coastal Lines and DTED Level 1-Generated Coastal Lines

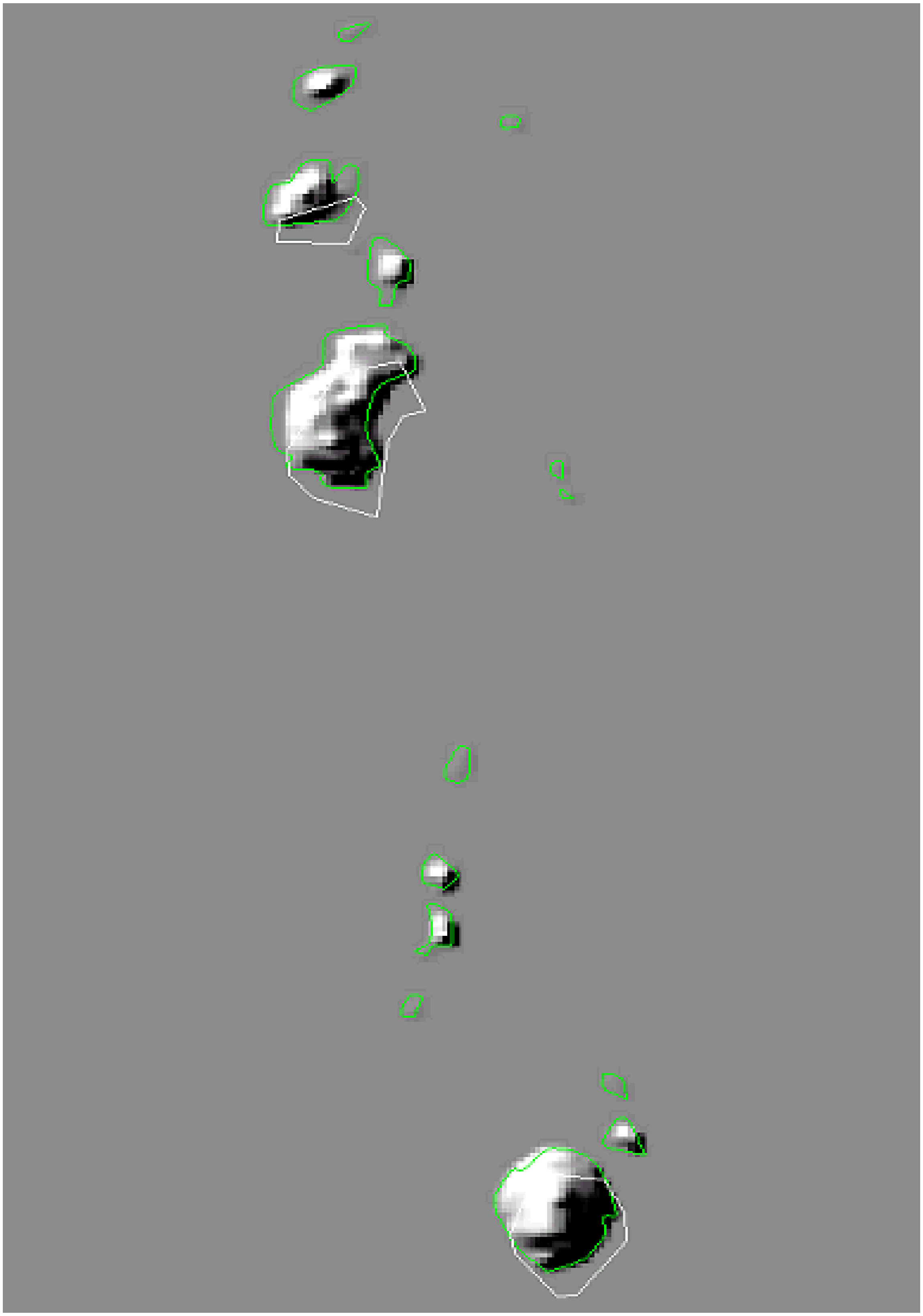

Figure 12. DCW Coastal Lines and DTED Level 1-Generated Coastal Lines

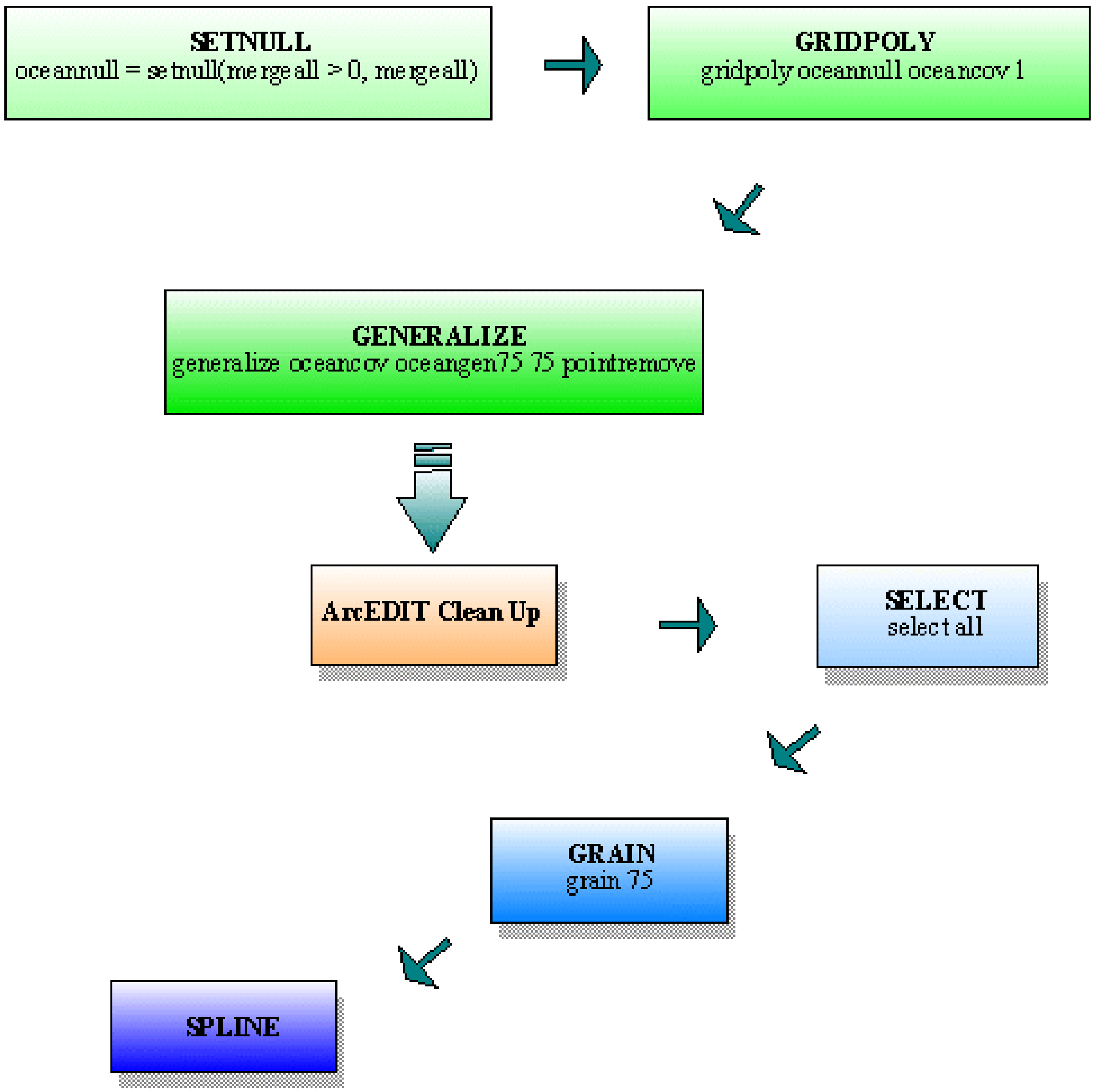

Figure 13. Flow Chart of the Coastal Generation Process

MERGING BATHYMETRY WITH DTED LEVEL 1

The DTED Level 1-generated coastal boundary will provide a tool to clip bathymetry and DTED Level 1 to a common boundary for the merging process. The most common source of bathymetry is available on the U.S. Department of Commerce's National Oceanic and Atmospheric Administration's (NOAA) National Data Center for Marine Geology and Geophysics at the Topography & Global Relief web site: www.ngdc.noaa.gov/mgg/bathymetry/relief.html. Click on the Global Relief & Elevation Models and click on the ETOPO5/TerrainBase to access the 5-Minute Gridded Elevation Data Selection web site. This is the web site where the bathymetric and global 5-minute terrain data can be downloaded to the computer in different formats. Any area can be selected by using the following coordinates: Upper Left (UL) longitude, latitude, and Lower Right (LR) longitude, latitude. The format chosen for this project was comma delimited, ASCII format, and Lon Lat Datavalue.

First, the downloaded data were converted from the ASCII format to a grid. This was done by using the xyz2grid.aml file seen in the Appendix, which can be download from the ESRI web site at www.esri.com under ArcInfo scripts. The AML was executed at the Arc prompt by typing the string *&r xyz2grid indian.xyz oceandd*. Second, the new grid had to be projected to a UTM projection, zone 47, and WGS 84 datum by using the *PROJECTGRID* command at the Arc prompt. The following command line was issued *projectgrid bathdd bathutm utm.prj* with a utm.prj file shown in Figure 14.

```
input
projection geographic
units dd
datum wgs84
parameters
output
projection utm
units meters
zone 47
datum wgs84
parameters
end
```

Figure 14. UTM.PRJ File

Third, the grid *bathutm* needed to have the same cell size as the DTED Level 1 data. The *RESAMPLE* function was issued with the following string *bathres90 = resample(bathutm, 90, bilinear)* at the GRID prompt. Fourth, the *bathres90* was clipped to the same area as DTED Level 1 by using a generated bounding box of the area. This was accomplished by using the *LATTICECLIP* command at the Arc prompt with the following command line *latticeclip bathres90 areaclip bathresclip minimum*. Fifth, the bathymetry was ready to be clipped by the DTED Level 1-generated coastal vectors. Two different coverages were created in ArcEdit to produce the desired effect. The first coverage used the coastline with island boundaries to clip the DTED Level 1 terrain shown in Figure 15. The second coverage used the entire ocean area to clip the bathymetry shown in Figure 16. The command *LATTICECLIP* from step 4 was used to clip the DTED Level 1 and bathymetry using the two different coverages. Sixth, the *INT* function was issued at the GRID prompt to convert the clipped bathymetry data to DTED Level 1 integer values using the string *oceanint = int(oceanresclp)*.

Seventh, NODATA values for the islands are created and provide data to complete the merging process correctly. This was done by selecting the ocean and island polygons from the DTED Level 1-generated coastal vectors. The ocean and island polygons were dumped into a new coverage by using the *PUT* command. An *elev* attribute field was added to the new ocean/island polygons. The ocean polygon was given a value of 0 and the island polygons were given a value of -9999, which is a NODATA value. Eighth, the ocean and island polygons were converted to a grid by using the *POLYGRID* command with the string *polygrid islandcov islandmask elev* at the Arc prompt. Ninth, the *SELECTMASK* function was used to mask out the islands from the clipped bathymetry. The following string was used to execute the process *oceanmask = selectmask (oceanclp, islandmask)* at the GRID prompt. The result of the masking is shown in Figure 18 with the before-masking result shown in Figure 17.

Tenth, the *GRIDINSERT* command was used to merge the clipped DTED Level 1 and masked bathymetry with the update option using the command line *gridinsert oceanmask thailandclp landocean update* at the Arc prompt. The result of the *GRIDINSERT* command is shown in Figure 19 with black areas near the coastline indicating NODATA values. The bathymetry elevations in the first bathymetry/terrain merge were found to be higher in certain coastal locations, shown in Figure 19, by the bathymetry appearing higher than the land. A listing of the bathymetry was made using the *LIST* command at the GRID prompt by using *list oceanmask.vat*. The highest value found from the listing was 331 m. The *CON* function was used to select values greater than -11 m to correct all the inlet waterways. The string *oceancorr = con(oceanmask > -11, -10, oceanmask)* was used to perform this correction. The bathymetry and terrain data sets were merged again using the *GRIDINSERT* command with the results shown in Figure 20. In the final step, the *CON* and *ISNULL* functions were issued at the GRID prompt to eliminate the NODATA values on the coastline. The string *landocnisnl = con(isnull(landocean), 0, landocean)* was used for the final process to make the NODATA values equal 0 with the results seen in Figure 21. In Figure 22, the final delivered merged bathymetric/terrain data set is shown in a color-shaded relief.

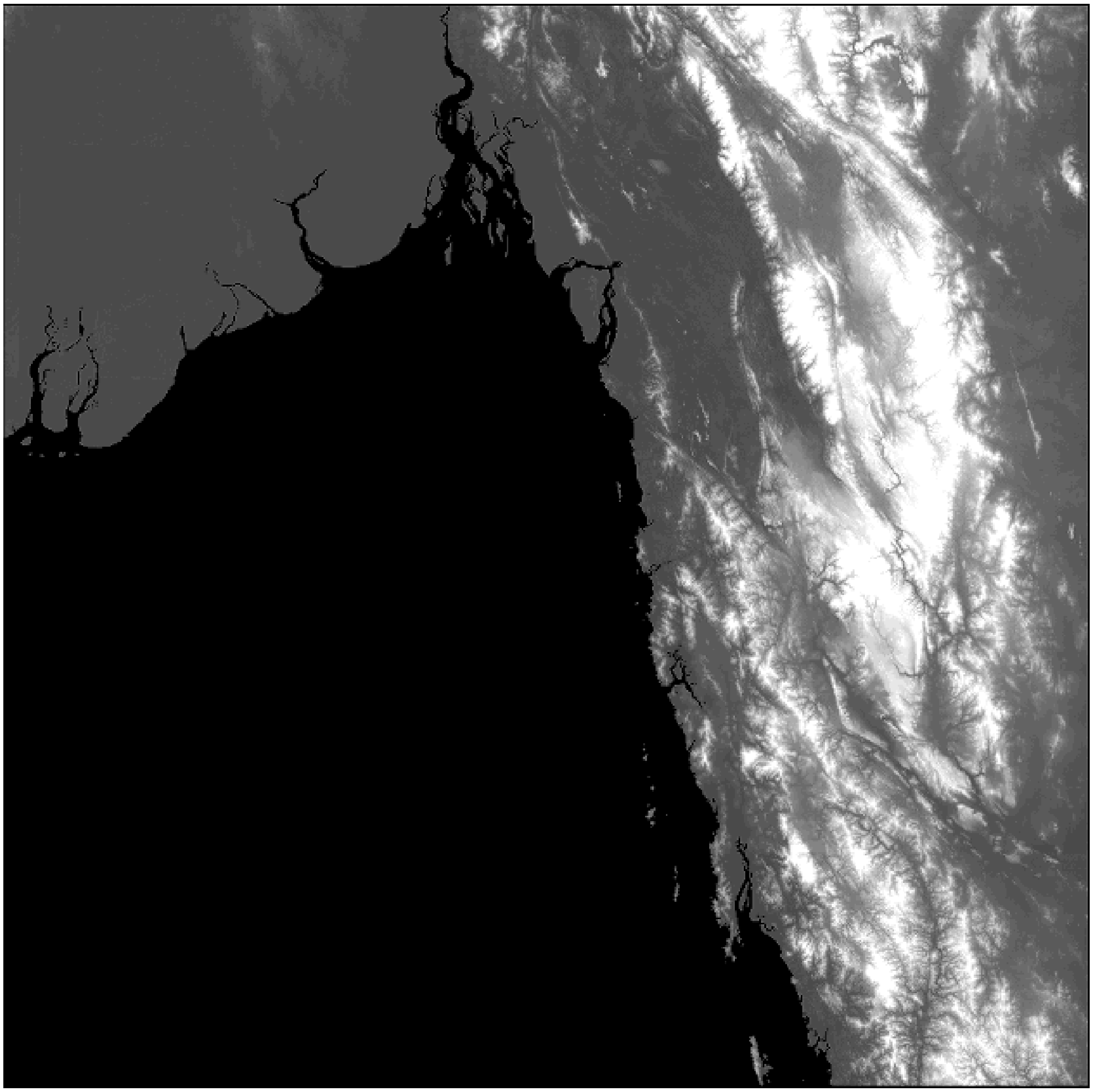

Figure 15. DTED Level 1 Clipped to Coastal Lines

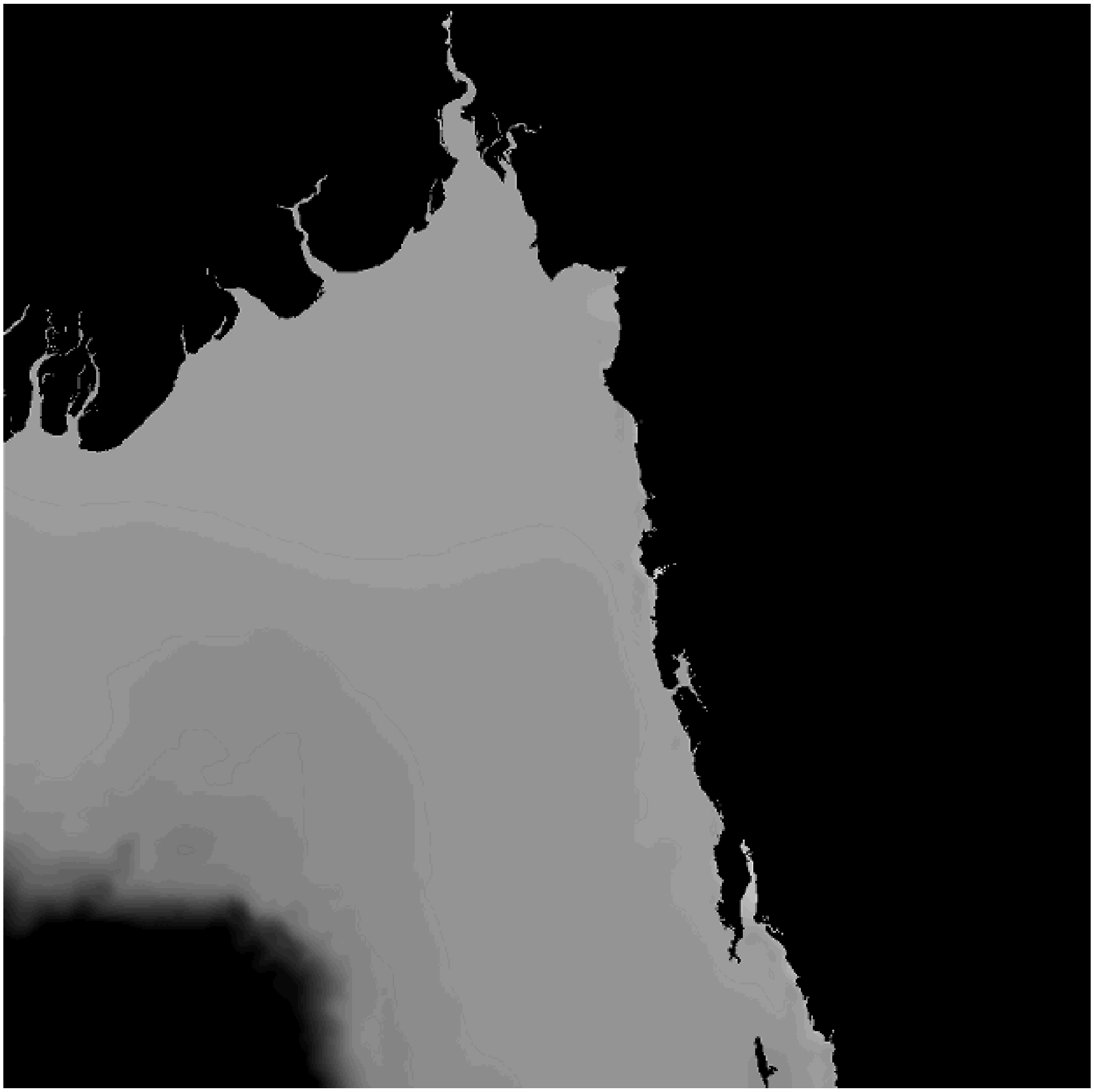

Figure 16. Bathymetry Clipped to the Coastal Lines

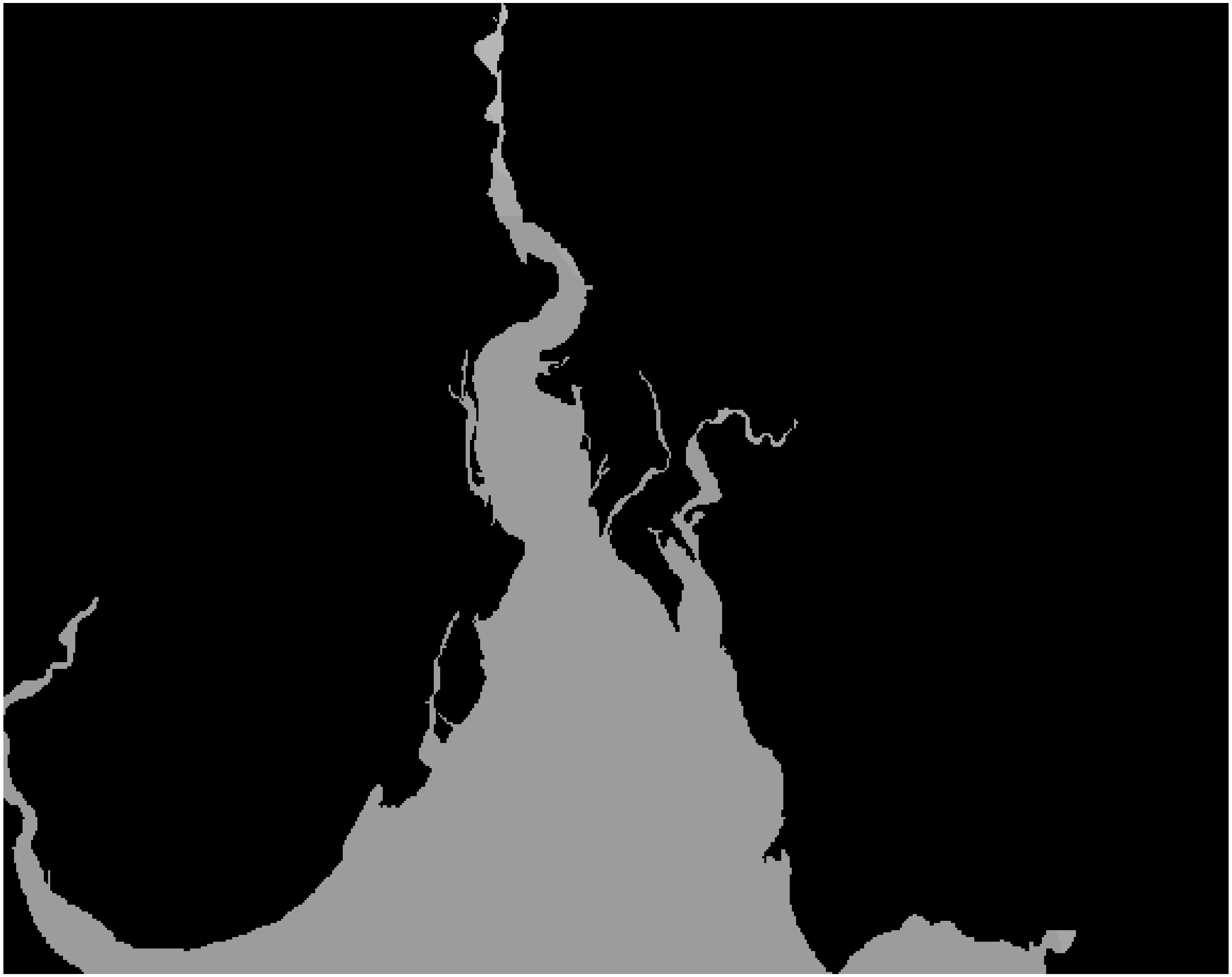

Figure 17. Before the *SELECTMASK* Function

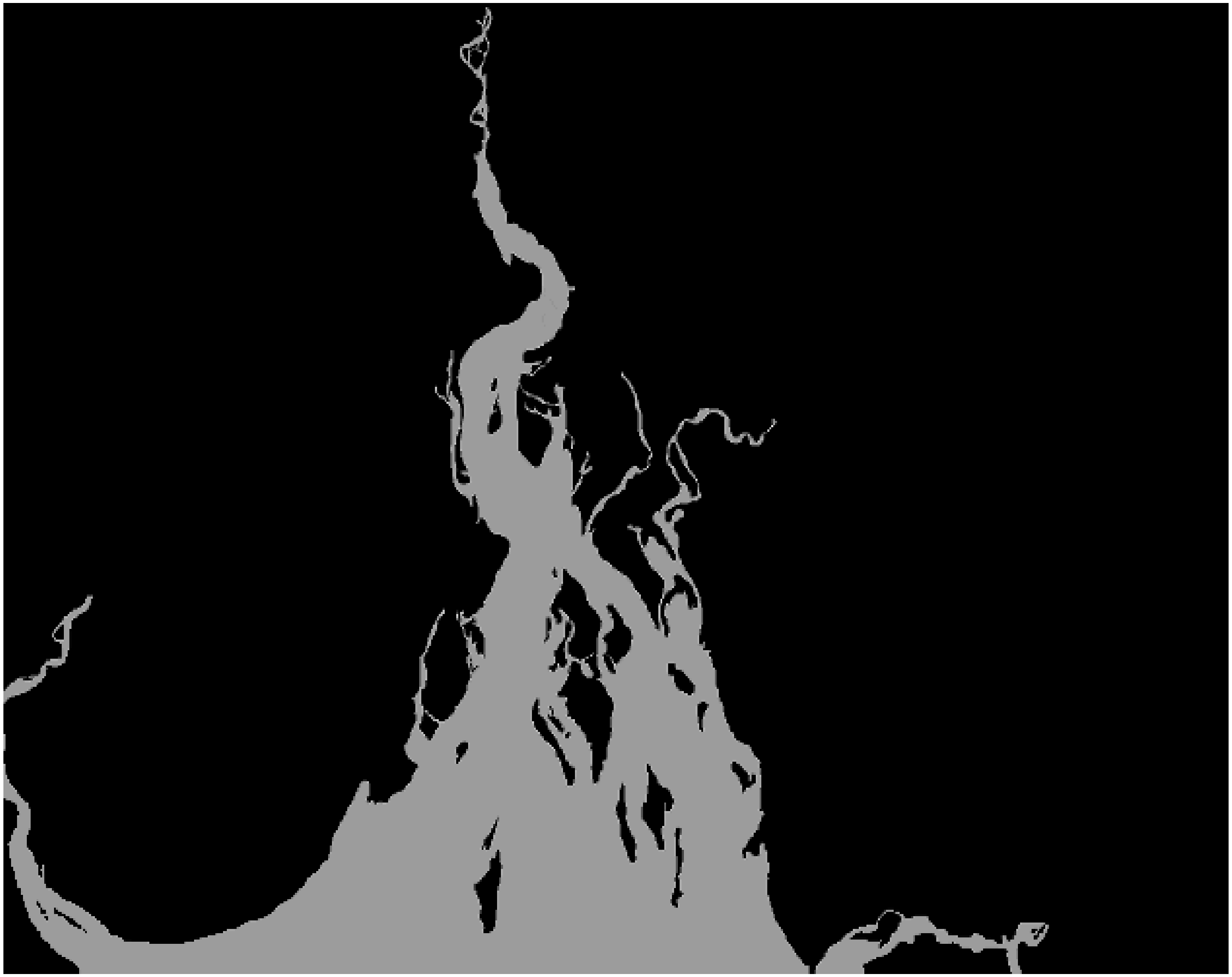

Figure 18. After the *SELECTMASK* Function

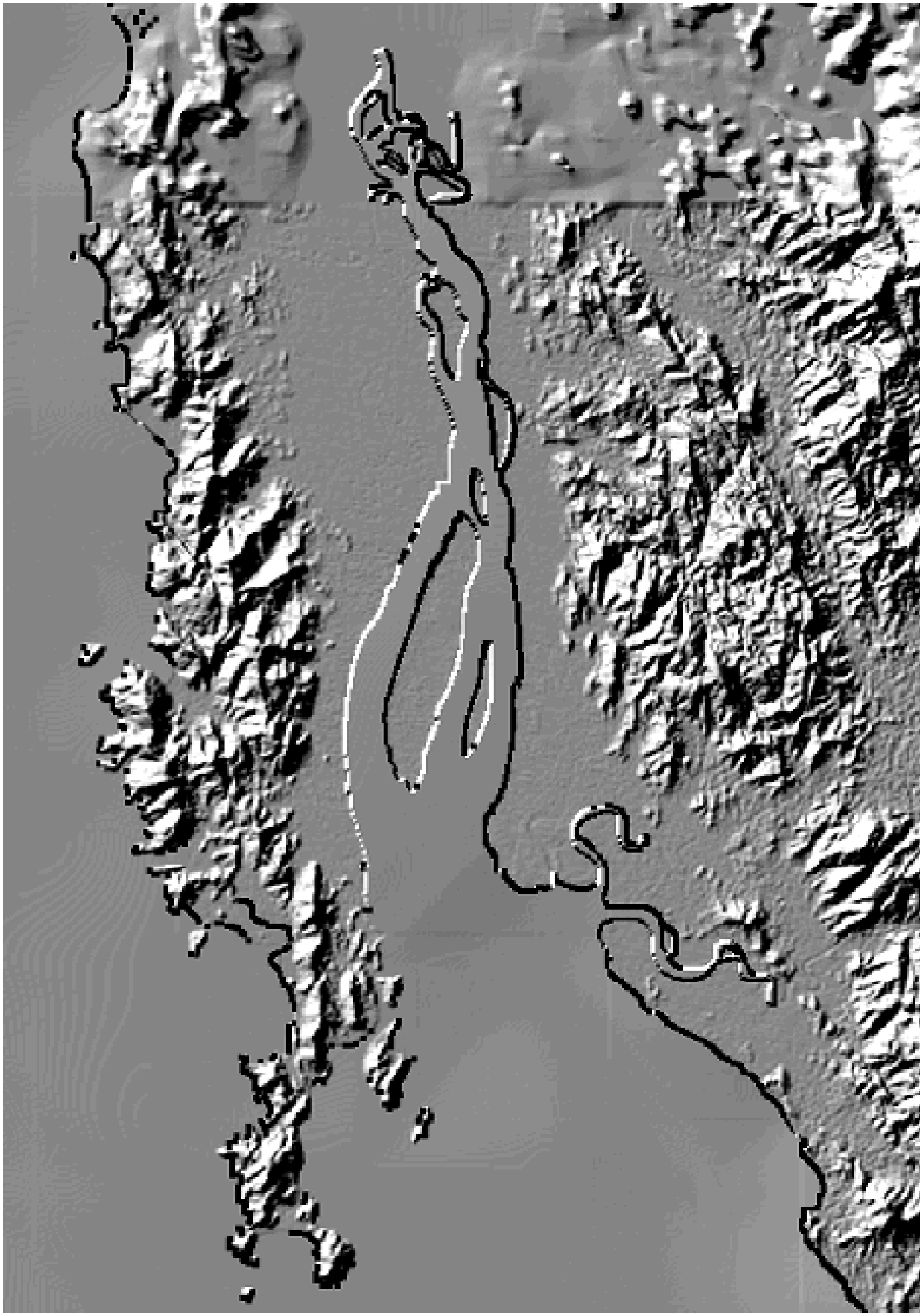

Figure 19. After the *GRIDINSERT* Command

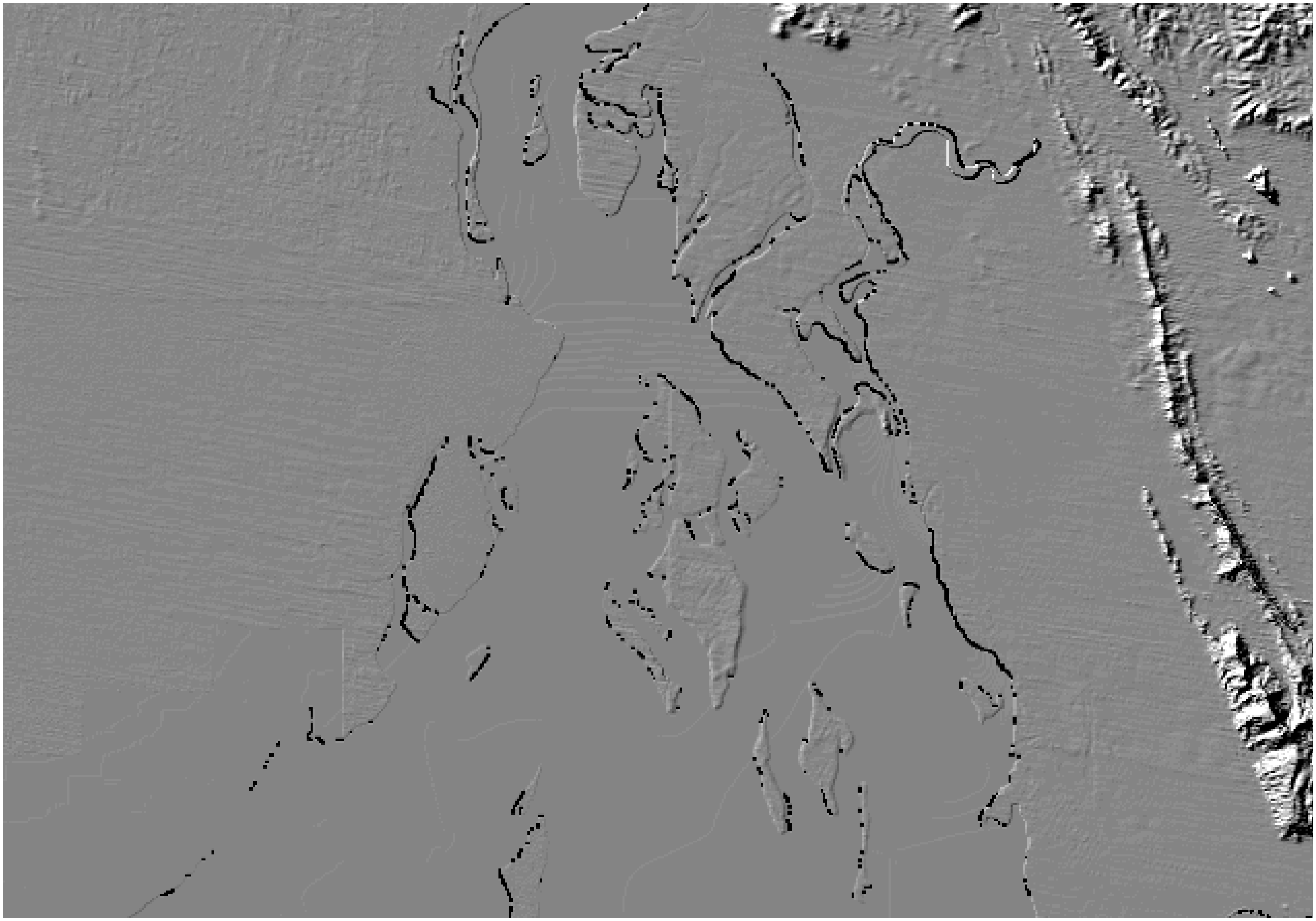

Figure 20. After the *CON* Function

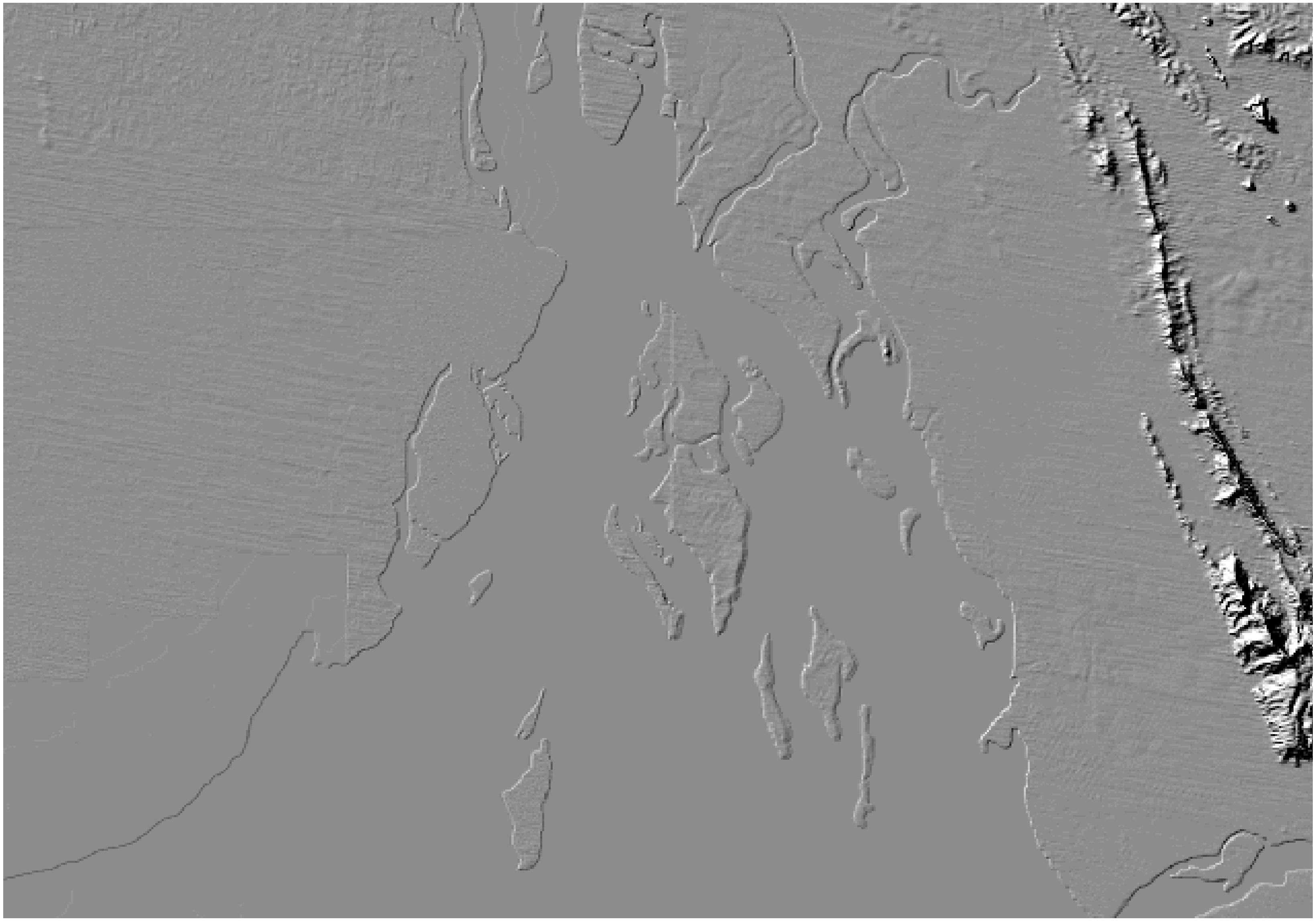

Figure 21. After the *CON* and *ISNULL* Function

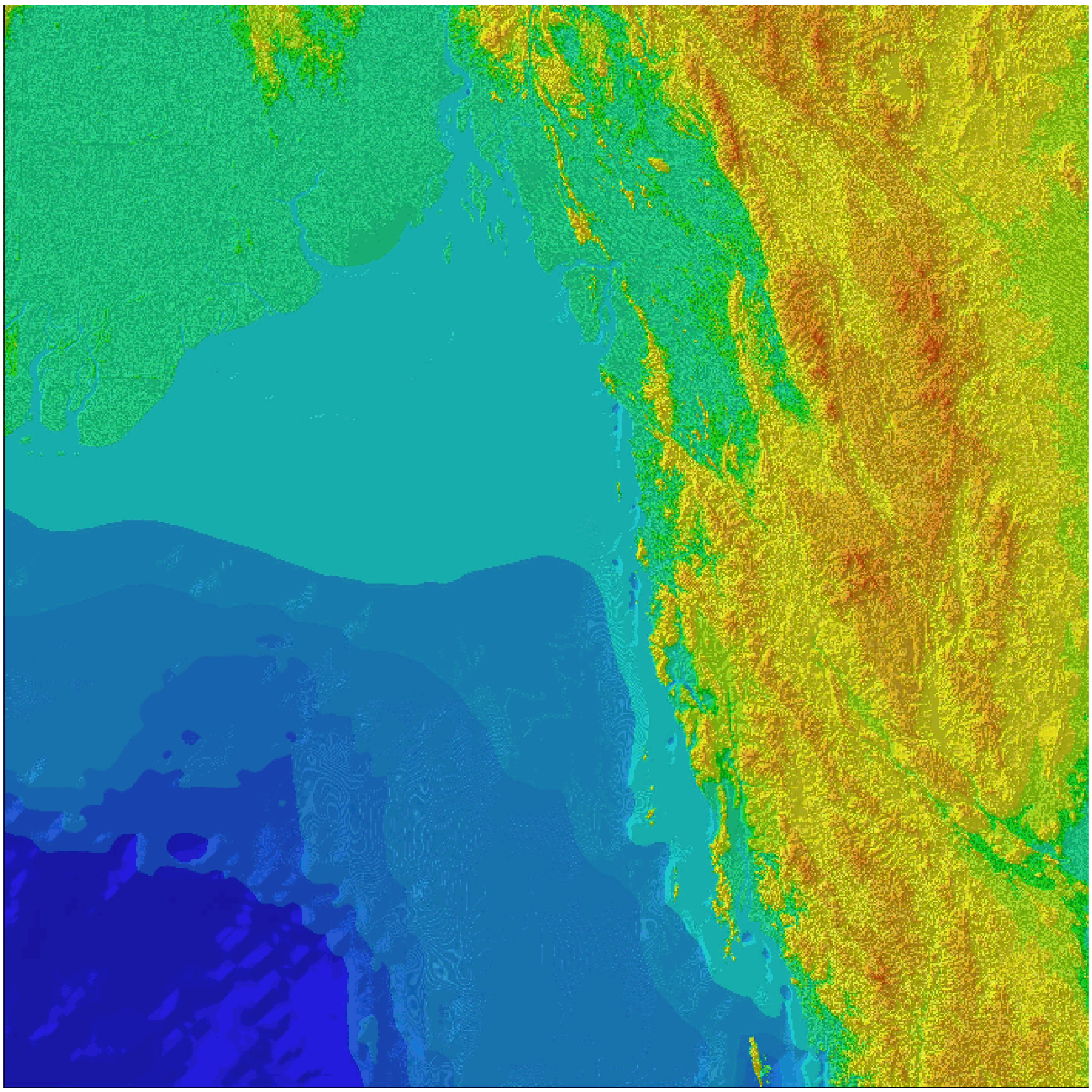

Figure 22. Color-Shaded Relief of Bathymetry/Terrain Merge

In the final step, it might not make sense to replace NODATA values with 0 values. This is just an approximation of the coastal boundary. The coastal boundary vectors in modeling and simulation are used to help build a TIN and make the coastal ocean-land boundary equal to 0 elevation. The elevation in the real world may be some other value. This approximation is suitable for modeling and simulation because of the increase in correlation between the ocean-land boundary not before possible in other construction efforts. The steps involved in the merging process are illustrated in Figure 23.

CONCLUSIONS

A coastal boundary line, which can be generated from DTED Level 1, will correlate better to the DTED Level 1 data than the DCW coastal boundary lines. The coastal boundary method allows for the generation of vectors for a modeling and simulation database, which correlates well with DTED Level 1 data when no other sources are available. The generation of coastal vectors seems to increase the number of features, such as islands. The coastal boundary vector also was used to clip DTED Level 1 and bathymetry to a common coastal boundary for the merging process.

The coastal boundary vectors and enhanced bathymetric/terrain data provide information not previously available to modeling and simulation for maneuvers by joint land, sea, and air operations using ArcInfo commands and functions. The coastal boundary method will guarantee a correlated result. The proposed methods can work with any elevation data set. Further investigation is needed to see if other data sets correlate better to DTED Level 1 and future DTED products for modeling and simulation. Additional research is needed to study the correlation between higher resolution vector data sets and DTED products, as well as between higher resolution elevation data sets.

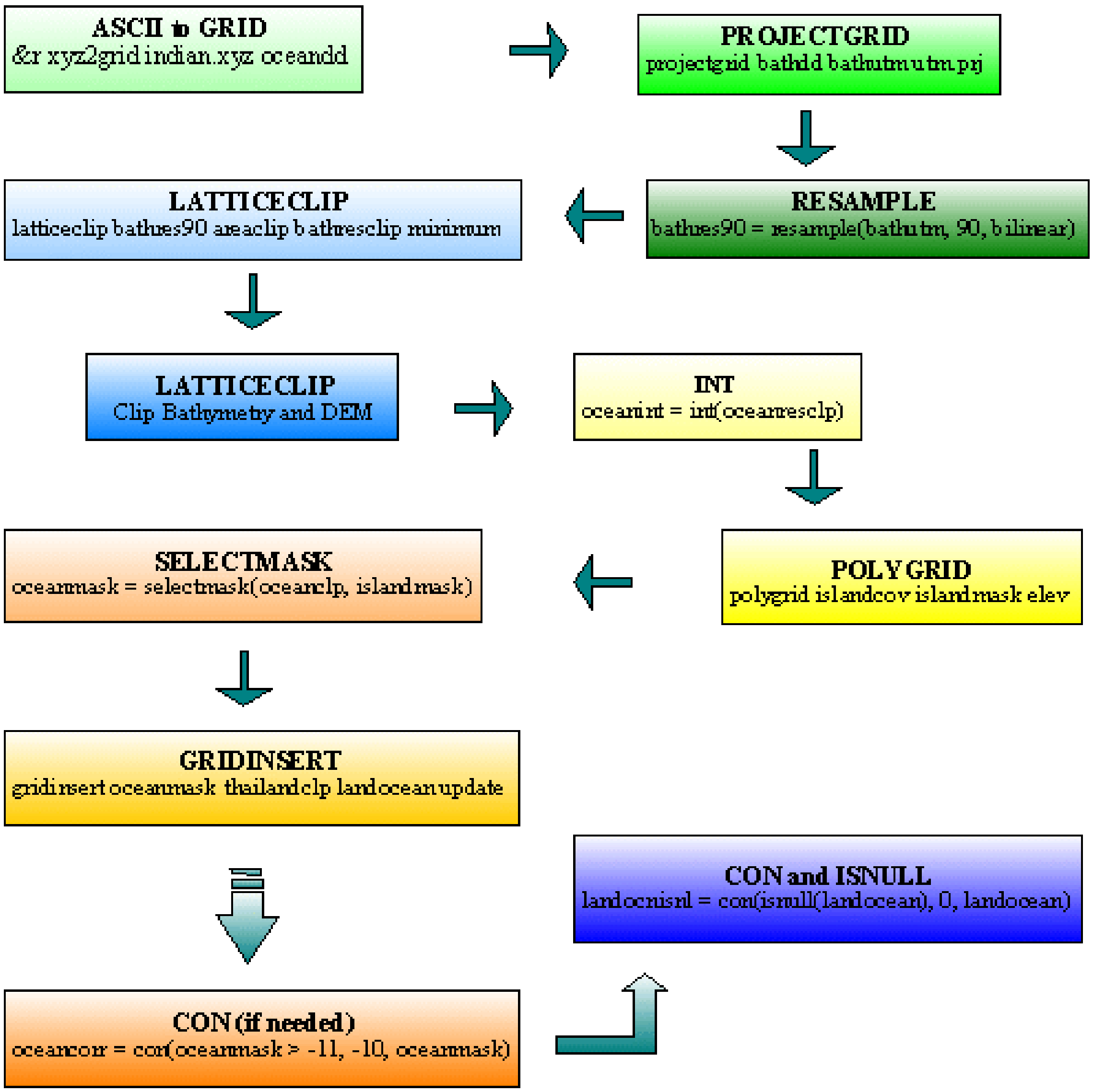

Figure 23. Flow Chart of the Merging Process

APPENDIX - XYX2GRID.AML

```
/* xyx2grid.aml
/*
/* Creates a grid from a textfile containing X,Y,Z values.
/*
/* History
/* Stephen Lead, Original coding - 21 Jan, 2000
/*
/*
&severity &error &routine bailout
&args textfile grid

&call checkargs
&call fileman
&call writefiles
&call generate
&call finish

&return

/*
&routine generate

  /* Generate the point cover.
  &s cover [scratchname -prefix xyz -directory]
  generate %cover%
  input %tempfileXY%
  points
  quit
  build %cover% points

  /* Create an INFO file from the Z values.
  &s zlist [scratchname -prefix xyz -info]
  tables
  define %zlist%
  %cover%-id 4 5 b
  elevation 10 10 n 4
  ~
  add from %tempfileZ%
  commit
  quit

  /* Join the cover with the elevation values.
```

```
  joinitem %cover%.pat %zlist% %cover%.pat %cover%-id %cover%-id

  /* We get the cellsize by subtracting the distance between the first 2
  /*points in the textfile.

  &s fileunit [open %textfile% openstat -read]
  &if %openstat% <> 0 &then
    &do
    &s str Error opening textfile %textfile%; &call bailout
    &end
  &s X1 [extract 1 [read %fileunit% readstat]]
  &s X2 [extract 1 [read %fileunit% readstat]]
  &if %readstat% <> 0 &then
    &do
    &s str Error reading textfile %textfile%; &call bailout
    &end
  &s null [close %fileunit%]

  &s gridsize [calc %x2% - %x1%]
  &if %gridsize% LE 0 &then
    &do
    &s str Error setting output grid size; &call bailout
    &end

  /* Finally, we do the point to grid conversion.
  pointgrid %cover% %grid% elevation
  %gridsize%
  yes
  nodata

  &return

/*
&routine writefiles

  /* Write the ID and XY to one file, the ID and Z to another. We need to
  /* check that the values in the textfile are numeric.

  &s ID = 0
  &s line [read %infileunit% readstat]

    &do &while %readstat% = 0
    &s ID = %ID% + 1
    &s x [extract 1 %line%]
```

```
    &s y [extract 2 %line%]
    &s z [extract 3 %line%]

    /* Check that values in the textfile are numeric.
    &if [null %x%] | [null %y%] | [null %z%] | ~
       [type %x%] > -1 | [type %y%] > -1 | [type %z%] > -1 &then
      &do
      &s str Bad value encountered in %textfile%: %line%
      &call bailout
      &end

    &s outlineXY [quote %ID% %x% %y%]
    &s outlineZ [quote %ID% %z%]
    &s writestatXY [write %XYfileunit% %outlineXY%]
    &s writestatZ [write %Zfileunit% %outlineZ%]
    &if %writestatXY% <> 0 | %writestatZ% <> 0 &then
      &do
      &s str Error writing to temporary textfile;&call bailout
      &end
    &s line [read %infileunit% readstat]
    &end

  /* Append the word END to the XY file.
  &s writestatXY [write %XYfileunit% END]
  &if %writestatXY% <> 0 &then
    &do
    &s str Error writing to temporary textfile;&call bailout
    &end

  &s null [close %XYfileunit%]
  &s null [close %ZFileunit%]

  &return

/*
&routine fileman

  /* Open the textfile.
  &s infileunit [open %textfile% openstat -read]
  &if %openstat% <> 0 &then
    &do
    &s str Error opening textfile %textfile%; &call bailout
    &end
```

```
  /* Create a temporary textfile to hold the ID and X,Y values.
  &s tempfileXY [scratchname -prefix xyz -file]
  &s XYfileunit [open %tempfileXY% openstat -write]
  &if %openstat% <> 0 &then
    &do
    &s str Error writing temporary textfile. Please check write permissions.
    &call bailout
    &end

  /* Create a temporary textfile to hold the ID and Y values.
  &s tempfileZ [scratchname -prefix xyz -file]
  &s Zfileunit [open %tempfileZ% openstat -write]
  &if %openstat% <> 0 &then
    &do
    &s str Error writing temporary textfile. Please check write permissions.
    &call bailout
    &end

  &return

/*
&routine checkargs

  &if [null %textfile%] | [quote %textfile%] = '#' &then &call usage
  &if [null %grid%] | [quote %grid%] = '#' &then &call usage
  &if [quote %textfile%] = 'usage' &then &call usage
  &if not [exist %textfile% -file] &then
    &do
    &s str Can't find textfile %textfile%; &call bailout
    &end
  &if [exist %grid% -grid] | [exist %grid% -cover] &then
    &do
    &s str Geodataset %grid% already exists; &call bailout
    &end

 &return

/*
&routine finish

  /* Delete the temporary files, covers, etc.
  &s null [delete %tempfileXY% -file]
  &s null [delete %tempfileZ% -file]
  &s null [delete %zlist% -info]
```

```
  kill %cover% all

  &s str Grid %grid% with cellsize %gridsize% was generated from %textfile%...
  &call bailout

  &return

/*
&routine usage

  &s str Usage &r %aml$file% <xyz_textfile> <grid>
  &call bailout

/*
&routine bailout

  &severity &error &fail

  /* Delete the temporary files and cover, if they've been created.
  &s null [close -all]
  &if [variable tempfileXY] &then &s null [delete %tempfileXY% -file]
  &if [variable tempfileZ] &then &s null [delete %tempfileZ% -file]
  &if [variable cover] &then
    &if [exists %cover% -cover] &then kill %cover% all

  &if not [variable str] &then &s str Bailing out of %aml$file%
  &return; &return &warning %str%

/*
/* END OF FILE
/*
```